Mon. Not. R. Astron. Soc. **000**, 000–000 (0000) Printed 1 February 2008 (MN LaTeX style file v1.4)

X-ray absorption in the strong FeII narrow-line Seyfert 1 galaxy Markarian 507

K. Iwasawa, W.N. Brandt* and A.C. Fabian

Institute of Astronomy, Madingley Road, Cambridge CB3 0HA
* *Present address: The Pennsylvania State Univeristy, Department of Astronomy and Astrophysics, 525 Davey Park PA 16802, USA*

ABSTRACT

We present results from spectral analysis of ASCA data on the strong FeII narrow-line Seyfert 1 galaxy Mrk 507. This galaxy was found to have an exceptionally flat ROSAT spectrum among the narrow-line Seyfert 1 galaxies (NLS1s) studied by Boller, Brandt & Fink (1996). The ASCA spectrum however shows a clear absorption feature in the energy band below 2 keV, which partly accounts for the flat spectrum observed with the ROSAT PSPC. Such absorption is rarely observed in other NLS1s. The absorption is mainly due to cold (neutral or slightly ionized) gas with a column density of (2–3)$\times 10^{21}$cm^{-2}. A reanalysis of the PSPC data shows that an extrapolation of the best-fit model for the ASCA spectrum underpredicts the X-ray emission observed with the PSPC below 0.4 keV if the absorber is neutral, which indicates that the absorber is slightly ionized, covers only part of the central source, or there is extra soft thermal emission from an extended region. There is also evidence that the X-ray absorption is complex; an additional edge feature marginally detected at 0.84 keV suggests the presence of an additional high ionization absorber which imposes a strong OVIII edge on the spectrum. After correction for the absorption, the photon index of the intrinsic continuum, $\Gamma \simeq 1.8$, obtained from the ASCA data is quite similar to that of ordinary Seyfert 1 galaxies. Mrk 507 still has one of the flattest continuum slopes among NLS1, but is no longer exceptional. The strong optical FeII emission remains unusual in the light of the correlation between FeII strengths and steepness of soft X-ray slope.

Key words: galaxies: individual: Mrk 507 – galaxies: active – X-rays: galaxies.

1 INTRODUCTION

Mrk 507 is a narrow-line Seyfert galaxy at a redshift of $z = 0.0559$ (Halpern & Oke 1987). Although this object had been classified as a Seyfert-2 galaxy or a LINER based on the permitted line width (FWHM$\sim$ 800km s^{-1}; Koski 1978) and line ratios (Heckman 1980), the detection of strong optical FeII permitted lines and a small [OIII]λ5007/Hβ ratio favours classification as a narrow line Seyfert 1 galaxy (NLS1; Halpern & Oke 1987). NLS1 were first studied by Osterbrock & Pogge (1985); they have optical spectra which are similar to those of normal Seyfert 1 galaxies but the Balmer lines are narrow, typically with FWHM$\leq$ 2000km s^{-1}. A prototype of this class of galaxy is I Zw 1 (see Goodrich 1989 for the classification criteria in optical emission-line spectra for NLS1).

NLS1s are different from ordinary Seyfert galaxies in their soft X-ray properties, as shown by ROSAT observations. Rapid, large amplitude X-ray variability and the lack of evidence for internal X-ray absorption strongly suggest that we are seeing direct radiation from an unobscured central source. This is consistent with the large X-ray luminosities of NLS1s as previously pointed out by Halpern & Oke (1987). Another remarkable X-ray property is their steep soft X-ray spectra. As shown in the ROSAT 0.1–2.4 keV photon-index–FWHM(Hβ) diagram of Boller, Brandt & Fink (1996, hereafter BBF), photon indices ranging from 3.5 – 5 are only found in NLS1. Although the ROSAT photon indices for NLS1s are spread over a wide range (Γ = 2–5), the mean value ($\Gamma_{\rm NLS1} \simeq 3.1$) is significantly larger than that ($\Gamma_{\rm Sy1} \simeq 2.3$) for ordinary Seyfert 1 galaxies with broad Balmer lines (BBF). This may be related to an intrinsic difference in the emission mechanism.

Mrk 507, which is an optically-classified NLS1, stands out since it shows an exceptionally flat ROSAT spectrum for any type of Seyfert 1 galaxy ($\Gamma = 1.6 \pm 0.4$, BBF). Although possible X-ray flux variations were detected from the ROSAT observations, the flat ROSAT spectrum does not fit the general properties of NLS1s (BBF). The best-fit value of the photon index is flatter by ~ 0.7 than even the mean

ROSAT value for ordinary Seyfert 1 galaxies. This could be taken to suggest that the spectral slopes of NLS1s vary widely between individual objects, in contrast to those of ordinary Seyfert 1 galaxies, which are found in a relatively tight range. However, it is also possible that the flat spectrum is due to a complicated absorption effect which cannot be resolved by the ROSAT PSPC because of its poor spectral resolution and limited energy range. Indeed, a strong anti-correlation between ROSAT spectral slope and FWHM(Hβ) is found in a sample of quasars studied by Laor et al (1997), which are presumably less absorbed than Seyfert galaxies, i.e., it appears that no flat X-ray spectrum quasars with narrow Balmer lines are found.

Since a large fraction of Seyfert 1 galaxies has been known to show evidence for absorption by partially-ionized gas, the so-called "warm absorber" (Halpern 1984) from a systematic study of ASCA X-ray spectra (e.g., Reynolds 1997), similar absorption effects can be expected in X-ray spectra of NLS1s. Unlike the absorption by cold material found in many Seyfert 2 galaxies due to the obscuring torus, X-rays are absorbed mainly by partially-ionized oxygen in the energy range between 0.5–2 keV in the case of a warm absorber. The energy where the deepest feature appears depends on the ionization state of the absorber.

Our ASCA observation was aimed at investigating whether the remarkably flat ROSAT spectrum of Mrk 507 is the result of such absorption effects or if indeed it has an intrinsically flat X-ray continuum. Previous hard X-ray obsevations of Mrk 507 with non-imaging collimated instruments, such as the Ginga LAC, were confused by the brighter Seyfert 1 galaxy Kaz 163 which is $\sim$ 10 arcmin SW of Mrk 507, so no spectral study of Mrk 507 in the energy band above 2 keV has ever been made.

A value of the Hubble parameter of $H_0 = 50$ km s^{-1} Mpc^{-1} and a cosmological deceleration parameter of $q_0 = \frac{1}{2}$ have been assumed throughout.

2 OBSERVATIONS AND DATA REDUCTION

Mrk 507 was observed by ASCA on 1995 December 16. The Solid-state Imaging Spectrometers (SIS) were operated in 2CCD/Faint mode. The lower level discriminator for the SIS was set at 0.47 keV to prevent the telemetry from being saturated by the hot pixels of the CCDs. This enabled us to use Faint mode throughout the observation. In both SIS (S0 and S1), the most well-calibrated CCD chip was used for Mrk 507, and the other was used for the nearby Seyfert 1 galaxy Kaz 163 ($z = 0.063$). Kaz 163 was at the edge of its chip with an off-axis angle $\sim$ 10 arcmin. About half of the photons for Kaz 163 collected by the X-ray telescope were lost due to this pointing configuration, which was the best possible given restrictions on satellite operation. The two objects were well within the fields of view of the Gas Imaging Spectrometers (GIS; G2 and G3). The net exposure time was about 37.9 ks for the SIS and 34.8 ks for the GIS. The data reduction and analysis were performed using FTOOLS and XSPEC provided by the ASCA Guest Observer Facility at Goddard Space Flight Center. Spectral data for each source were taken from circular regions with radii of 4 arcmin for the SIS and 5 arcmin for the GIS, centred on each X-ray peak. Background data for the SIS were taken from local source-free regions on the same CCD chip for each source. In addition to the two Seyfert galaxies, a previously unidentified X-ray source was serendipitously detected by the GIS (see Fig. 1). We shall refer to this source as AX J1749+684, and give details on this object, including an optical follow-up observation, in a separate paper (Iwasawa et al 1997a). Background-subtracted count rates observed in each detector are shown in Table 1. In spectral fits, we use response matrices generated by SISRMG in FTOOLS for the SIS and the standard ones (version 4.0) provided by the GIS team for the GIS.

Table 1. Observed count rates in each detector for Mrk 507, Kaz 163 and AX J1749+684. The integration times are 37.9 ks for the SIS and 34.8 ks for the GIS. AX J1749+684 was located outside of the SIS field of view. No corrections for either XRT response or the vignetting of the detector have been made.

Object	S0	S1	G2	G3
	10^{-2} counts s^{-1}			
Mrk 507	1.65	1.26	1.16	1.62
Kaz 163	2.54	3.25	2.40	3.87
AX J1749+684	—	—	0.99	0.77

These three objects were also observed in a ROSAT PSPC pointing at Mrk 507 on 1993 August 8–10. The total exposure time for this pointing was 24.7 ks. Results on Mrk 507 (BBF) and Kaz 163 (Brandt et al. 1994) have been published. The public ROSAT data are reanalyzed here to obtain a consistent solution of the spectrum of Mrk 507.

For the results of spectral fits, we quote 90 per cent confidence errors for one parameter of interest.

3 RESULTS

As Mrk 507 is faint, the SIS data above 7 keV are unusable for spectral analysis. In order to avoid uncertainties in response matrices due to the level discriminator being set at 0.47 keV, we discard the SIS data below 0.6 keV. Spectral fitting was thus performed with the 0.6–7 keV SIS data and the 0.9–10 keV GIS data.

Fitting with a power-law to the data above 2 keV from all four detectors gives a marginally acceptable fit with $\chi^2 = 94.76$ for 78 degrees of freedom. This yields a photon index $\Gamma = 1.7^{+0.2}_{-0.3}$ and a loose constraint on absorption, $N_{\rm H} < 1 \times 10^{22}$cm^{-2}. An extrapolation of the power-law model with Galactic absorption, $N_{\rm H} = 4.3 \times 10^{20}$cm^{-2} (Stark et al 1992), below 2 keV shows a clear deficit of soft X-ray photons, probably due to absorption (Fig. 2).

When a power-law modified by cold absorption is fitted to the whole energy range of the ASCA data, the implied column density of cold material is $N_{\rm H} \approx 3 \times 10^{21}$cm^{-2} and photon index $\Gamma \approx 1.7$ (see Table 2). This fit however still leaves an excess below 0.9 keV, a characteristic feature when warm absorption is relevant (see Reynolds 1996). The inclusion of an additional absorption edge improves the quality of the fit by $\Delta\chi^2 = 6.9$ to $\chi^2 = 155.1$ for 152 degrees of freedom (see Table 2). The edge threshould energy and optical depth are $E_{\rm th} = 0.84 \pm 0.07$ keV and $\tau = 1.1 \pm 0.6$, respectively. The significance of the edge is about at the 95 per cent confidence level, according to the F-test (Bevington 1969). The edge feature is probably a mixture of edges due to O VII

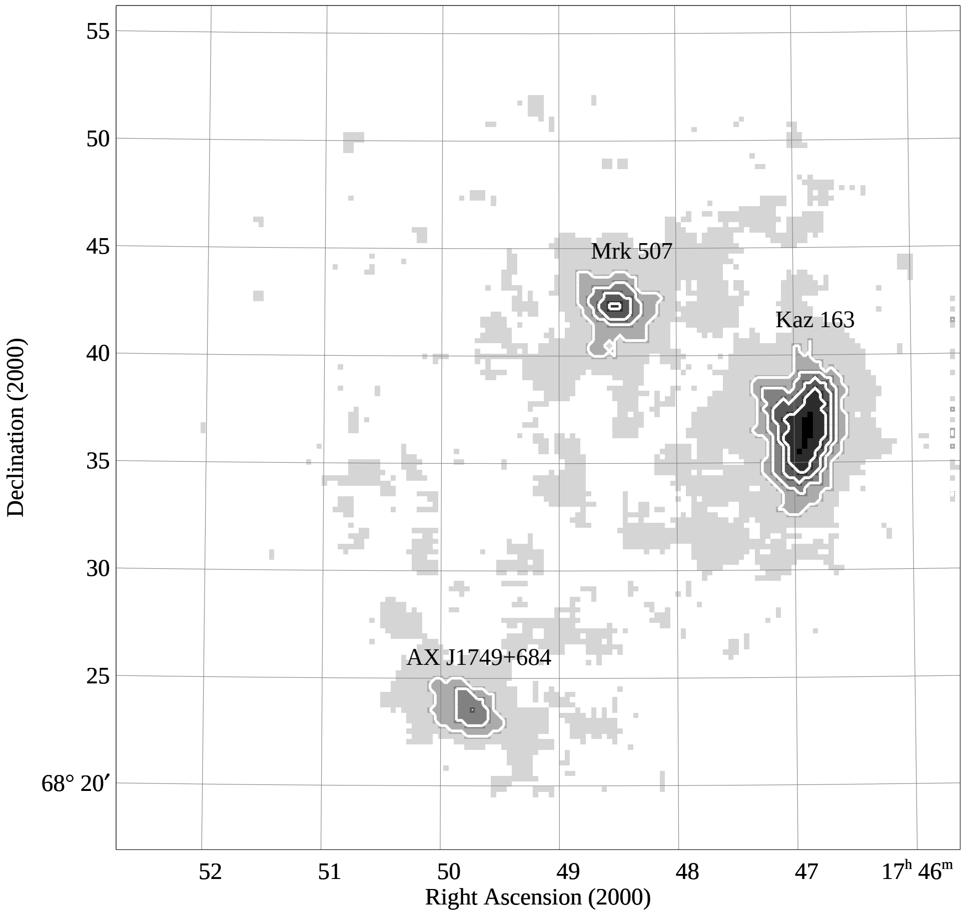

Figure 1. The ASCA GIS image (0.7–10 keV band) of Mrk 507, obtained by smoothing a summed G2+G3 image. Mrk 507, Kaz 163 and AX J1749+684 are labelled. Contours are at 33.3, 50.0, 66.6 and 83.3 per cent of the maximum pixel value (see the text for source normalizations).

(0.74 keV) and OVIII (0.87 keV), as seen in Seyfert 1 galaxies, although our data do not have sufficient signal-to-noise to resolve them. The relatively high edge energy suggests that OVIII could give a stronger absorption edge than OVII does. The photon index is $\Gamma = 1.84 \pm 0.2$, consistent with that obtained from a simple power-law fit to the 2–10 keV data. Significant cold absorption, $N_{\rm H}= 2.0^{+1.4}_{-0.7} \times 10^{21}{\rm cm}^{-2}$, is still required.

We also tried a partially covered power-law model. Compared to the uniformly-absorbed power-law model with warm absorber described above, the quality of the fit from this model is worse, and the improvement from the uniform absorber model is less significant (see Table 2). Therefore the best description for the absorption in the ASCA spectrum is the cold absorber with $N_{\rm H}\simeq 2 \times 10^{21}{\rm cm}^{-2}$ plus a warm absorber which imposes the ionized oxygen edge around 0.8 keV.

No significant iron Kα line at 6.4 keV is detected. Fitting the 2–10 keV data with a power-law plus a gaussian line width $\sigma = 0.4$ keV, the mean iron Kα line width of ASCA Seyfert 1 galaxy samples (Nandra et al 1996; Reynolds 1997), gives a 90 per cent upper limit on EW of 730 eV.

The observed ASCA fluxes in the 0.6–2 keV and 2–10 keV band are $f_{\rm 0.6-2keV} = 1.6 \times 10^{-13}{\rm erg\ cm^{-2}\ s^{-1}}$ and $f_{\rm 2-10keV} = 5.1 \times 10^{-13}{\rm erg\ cm^{-2}\ s^{-1}}$, respectively. The absorption-corrected luminosities in the same energy bands are $L_{\rm 0.6-2keV} = 4.5 \times 10^{42}{\rm erg\ s^{-1}}$ and $L_{\rm 2-10keV} = 7.2 \times 10^{42}{\rm erg\ s^{-1}}$.

We now consider the reason for the flat ROSAT spectrum. A simple power-law model gives a photon index $\Gamma = 1.6{\pm}0.4$ with no excess absorption above Galactic value (Fig. 3a and BBF). It is however clear from the ASCA spectrum (see Fig. 2) that almost the entire ROSAT band (≤ 2 keV) is affected by absorption. As no absorption-free continuum is seen by ROSAT, a simple power-law fit is misleading. The absorption detected by ASCA is a likely explanation for the flat ROSAT spectrum.

It should be noted that calibration uncertainties between ASCA and ROSAT currently remain. There is significant disagreement between ASCA and ROSAT spectral slopes in active galaxies (e.g., Yaqoob et al 1994; Fabian et al 1995); ROSAT spectra, especially ones taken after the gain change of the PSPC in 1991, often give steeper photon indices than ASCA spectra (by $\Delta\Gamma \sim$0.5, e.g., ASCA

Table 2. Spectral fitting results for the ASCA data. Four detectors are fitted jointly. The Galactic absorption, $N_{\rm H}= 4.3\times10^{20}{\rm cm}^{-2}$, is included in all fits. PL is a power-law model. The edge threshould energy is corrected for redshift $z = 0.056$. $*$ A cold absorber which covers the central source partially; † A covering fraction of the absorber.

ASCA 2–9 keV

Model	Γ	$N_{\rm H}$ $10^{21}{\rm cm}^{-2}$	χ^2/dof
PL	$1.7^{+0.4}_{-0.3}$	< 10	95.11/77

Whole ASCA band (0.6–9 keV)

Model	Γ	$N_{\rm H}$ $10^{21}{\rm cm}^{-2}$	$f_{\rm C}^{\dagger}$	$E_{\rm th}$ keV	τ	χ^2/dof
PL	$1.76^{+0.22}_{-0.20}$	$3.4^{+1.5}_{-1.3}$	1.0	—	—	162.0/154
PL + Edge	$1.84^{+0.21}_{-0.19}$	$2.0^{+1.4}_{-0.7}$	1.0	0.84 ± 0.07	1.1 ± 0.6	155.1/152
PL + PC*	$1.92^{+0.31}_{-0.26}$	$6.0^{+3.8}_{-3.7}$	0.79 (≥ 0.64)	—	—	159.7/153

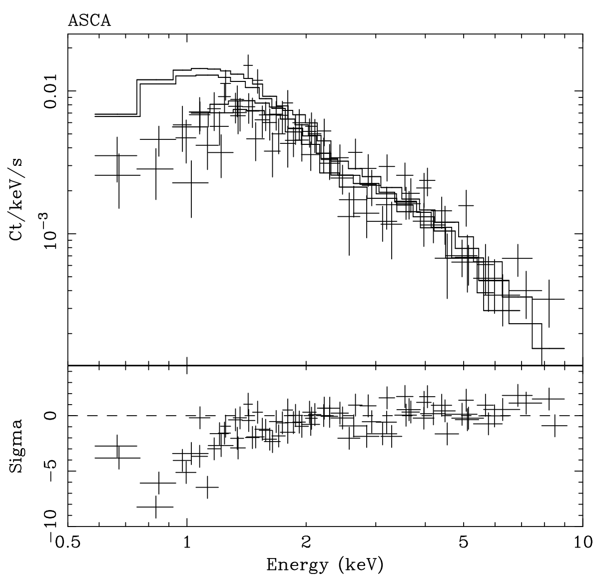

Figure 2. The ASCA spectra of Mrk 507 from four detectors. The solid line shows the best-fit power-law model with Galactic absorption fitted to the 2–9 keV data. An absorption feature is clearly seen below 1.5 keV in the residual plot.

GOF 1995). Actually this discrepancy between photon indices from the two satellites is confirmed by observations of the normal Seyfert 1 galaxy, Kaz 163, in the same field of view as Mrk 507. This shows a featureless power-law spectrum. A similar difference ($\Delta\Gamma\simeq 0.5$) between the ROSAT photon index ($\Gamma = 2.5\pm0.1$, Brandt et al 1994) and the ASCA one ($\Gamma = 2.0\pm0.1$) is found (although the two observations were not simultaneous). A comparison of Einstein Observatory IPC and ROSAT PSPC data of the EMSS AGN also gives a similar trend ($\Delta\Gamma = 0.4$–0.5, Ciliegi & Maccacaro 1996). The steepness of ROSAT spectra has often been reconciled by assuming strong soft excess emission in the ROSAT band. However, this is not the only reason and a cross-calibration error seems to also be important. Even in the 0.5–2 keV band where both the PSPC and the ASCA SIS are sensitive, a significant difference in spectral slope was found in simultaneous data on NGC5548 (Fabian et al 1994) and also for Kaz 163. A consistency in spectral slope measurement between ASCA and previous instruments such as the Einstein IPC, EXOSAT ME/LE and Ginga LAC is confirmed by observations of the Galactic synchrotron nebula 3C58 (Dotani et al 1996). Although uncertainties in response matrices for the SIS at energies around 0.5 keV, which could cause an error in absorption measurements by $\Delta N_{\rm H}\sim 2\times10^{20}{\rm cm}^{-2}$, are reported (Dotani et al 1996), this could not be a problem in our analysis because we discarded the data below 0.6 keV. Therefore at the current status of calibrations, $\Delta\Gamma\sim 0.5$ might be appropriate when ASCA and ROSAT data are compared.

We therefore naively assume a ROSAT photon index of 2.4 from the ASCA result ($\Gamma = 1.84\pm0.2$) and examine the PSPC data. It now fits well to the ROSAT data above 0.4 keV, when the power-law is modified by cold absorption with $N_{\rm H}= (1.7\pm0.5)\times10^{21}{\rm cm}^{-2}$ and an additional edge at the rest energy of 0.84 keV and optical depth $\tau\simeq 0.6(\leq 1.1)$, similar to the ASCA spectral fits (see Table 2). However, some excess emission is found above the model in the energy band below 0.4 keV, as illustrated in Fig. 3b. Cold absorption with the implied column density suppresses X-ray photons of those energies.

The excess emission can be explained by any of three possibilities; (1) replacing the cold absorber by a low ionization warm absorber; (2) a partially covering absorber; and (3) extra emission from an extended region. In the first case, the absorber is slightly ionized rather than neutral so that the spectrum would recover below 0.5 keV (see Fig. 3b). This absorber should be different from the one with the ionization parameter, $\xi = L/(n^2R)\sim 10^2$ which imposes the strong O VIII edge around 0.8 keV. If a photoionized absorber calculated by CLOUDY (Ferland 1996) is fitted, the best-fit parameters are $\xi\simeq 2$ and column density $N_{\rm W}\simeq 3\times10^{21}{\rm cm}^{-2}$. In the second case, some fraction of the central source escape from the cold absorber. If a partial covering model is fitted, the column density and covering fraction of the absorber are $N_{\rm H}= 2^{+2}_{-1}\times10^{21}{\rm cm}^{-2}$ and $f_{\rm C} = 0.75\pm0.1$, respectively. Finally, in the third case, thermal emission with a

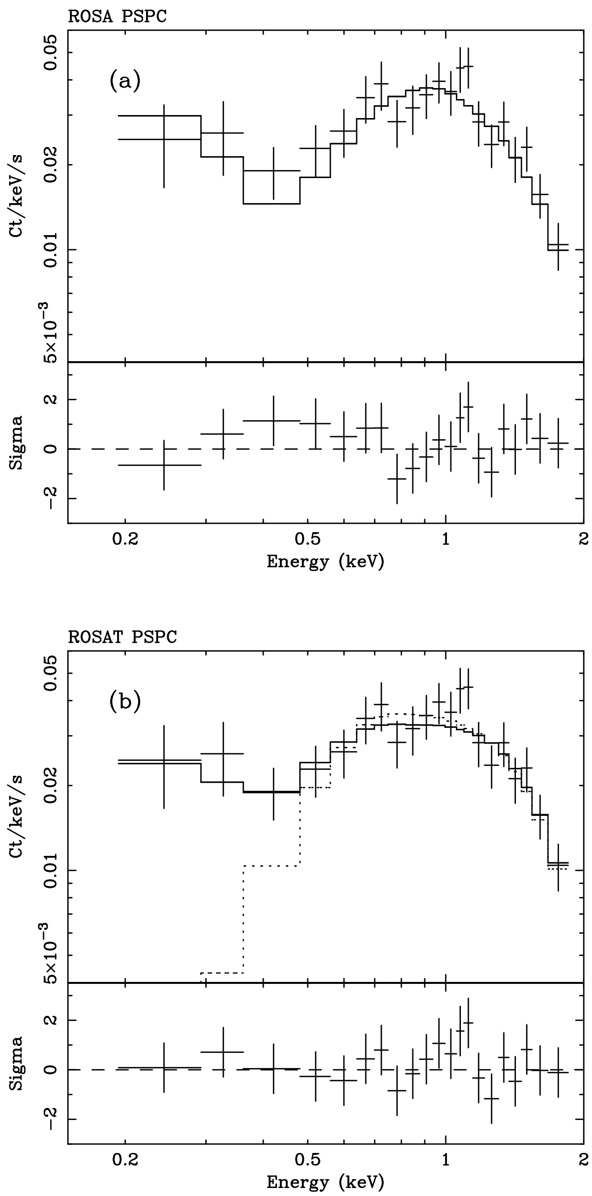

Figure 3. The ROSAT PSPC spectrum of Mrk 507 (BBF). (a) A simple power-law fit with $\Gamma \approx 1.6$ and $N_{\rm H} = 4 \times 10^{20}{\rm cm}^{-2}$. (b) A power-law with $\Gamma = 2.4$ modified by the 0.8 keV edge and cold absorption ($N_{\rm H} \approx 2 \times 10^{21}{\rm cm}^{-2}$; dotted line) or ionized absorption ($N_{\rm W} \approx 3 \times 10^{21}{\rm cm}^{-2}$ and $\xi \approx 2$; solid line). The residual plot is for the ionized absorber fit.

temperature of 10^7 K and luminosity of $\sim 10^{42}$erg s^{-1} must be associated with the galaxy. An extended optical emission line region has been found in Mrk 507 (Halpern & Oke 1987). Many nearby active galaxies having extended optical emission nebula, especially Seyfert 2 galaxies, show thermal emission in the soft X-ray band, although with much lower luminosities (e.g., Wilson, Elvis & Bland-Hawthorn 1992; Weaver et al 1994; Makishima et al 1994; Morse et al 1995; Iwasawa et al 1997).

4 DISCUSSION

Intrinsic absorption has been found in the ASCA spectrum of this narrow-line Seyfert 1 galaxy. It is likely that the absorption makes the ROSAT spectrum appear flat. The absorption is mainly due to a cold, or possibly low ionization, absorber with a column density of $(2–3)\times10^{21}$cm^{-2}. Soft X-ray emission is seen below 0.4 keV detected with the ROSAT PSPC, three options are possible (see Section 3.1); (1) the absorber is slightly ionized ($\xi \sim 2$); (2) the covering fraction of the absorber is less than unity ($\sim$ 75 per cent); and (3) there is extra thermal emission with a temperature of $\sim 10^7$ K. In any case, the excess soft X-ray emission, escaping from the absorption detected with ASCA, may be related to even lower energy emission claimed from Extreme Ultraviolet Expolorer data (Fruscione 1996). Note that the ASCA spectrum is not sensitive to the ionization of absorber (1), because the recovery of the spectrum is out of the ASCA bandpass (< 0.6 keV). An additional edge absorption feature at 0.84 keV is marginally detected (at ~95 per cent confidence level), implying another high ionization absorber ($\xi \sim 10^2$) which imposes a strong OVIII edge. Such a multi warm-absorber is not unusual in Seyfert 1 galaxies, as found in MCG–6-30-15 (Otani et al 1996), although the ionization parameters are different in Mrk 507. It should be noted that the cold absorption detected from Mrk 507 is unusual for NLS1s which normally show no evidence for cold absorber although some may have warm absorbers (e.g., Brandt et al 1994).

The intrinsic continuum slope of Mrk 507 is found to be $\Gamma \approx 1.8$ (see Table 2), similar to that of ordinary Seyfert 1 galaxies. It is in a good agreement with the mean value, $\Gamma = 1.81$ found for an ASCA sample of 24 Seyfert 1 galaxies (Reynolds 1997). This still does not fit the steep spectral nature of most of NLS1s, and means that Mrk 507 has the flattest photon index compared with other NLS1s with similar FWHM(Hβ) in the diagram of Γ–FWHM(Hβ) in BBF even after correction for absorption. The X-ray absorption may imply obscuration of the broad-line region which results in narrow width of the Balmer lines.

Mrk 507 is an extreme FeII AGN (FeII/H$\beta \simeq 2.9$, Lipari 1994). The rather normal continuum slope is then inconsistent with the correlation between soft X-ray slope and strength of optical FeII emission found from a study of Einstein Observatory IPC data (Wilkes, Elvis & McHardy 1987; see also Boroson 1989). A possible difference between Mrk 507 and steep-spectrum NLS1s is its X-ray luminosity. The total X-ray luminosity of Mrk 507 is about 1×10^{43}erg s^{-1} whilst steep-spectrum NLS1s have X-ray luminosities typically 10^{44}erg s^{-1} or larger (e.g., 2×10^{44}erg s^{-1} for I Zw 1, Halpern & Oke 1987; 3×10^{44}erg s^{-1} for IRAS 13224–3809, Boller et al 1993). There are other X-ray quiet AGNs with extreme FeII. Mrk 231 (Rigopoulou et al 1996) and IRAS 07598+6508 (Lawrence et al 1997) are typical of those. These FeII AGNs including Mrk 507 appear to be different from the powerful steep-spectrum NLS1s, and the relationship between strength of optical FeII emission and soft X-ray properties remains uncertain.

The far-infrared peaked SED (e.g., Lipari 1994), strong optical FeII, weak [OIII]λ5007 (EW is about 7 Å; J. Halpern, private communication) and evidence for significant intrinsic

X-ray absorption seen in Mrk 507 are also generally seen in broad absorption line quasars. It would be interesting to see if Mrk 507 also shows broad aborption lines in the ultraviolet due to absorption by the same material that we see with ASCA.

5 CONCLUSIONS

We detected significant absorption in the ASCA spectrum of a NLS1, Mrk 507, which plausibly causes the apparently flat spectrum in the ROSAT band measured by BBF. The absorber is neutral or possibly slightly ionized, and the column density is 2–3×10^{21}cm^{-2}, depending on models. In addition to the cold absorber, marginal evidence for an OVIII edge due to another warm absorber with high ionization parameter was found. The spectral slope of the intrinsic continuum is similar to ordinary Seyfert 1 galaxies rather than NLS1s that generally have steeper soft X-ray continua. As one of extreme FeII AGNs (Lipari 1994), this is also unusual in the light of the correlation between EW(FeII) and steepness of soft X-ray spectra claimed by Wilkes, Elvis & McHardy (1987).

ACKNOWLEDGEMENTS

We thank Jules Halpern for helpful discussions. We thank all the members of the ASCA team who maintain the satellite and carry out operations. ACF, KI and WNB thank the Royal Society, the PPARC, the Smithsonian Institution, respectively, for support.

REFERENCES

ASCA Guest Observer Facility (GOF), 1995, http : //heasarc.gsfc.nasa.gov/docs/asca/ahp_proc_analysis.html
Awaki H., 1991, PhD thesis, Nagoya University
Bevington P., 1969, Data Reduction and Error Analysis for the Physical Sciences. McGraw Hill, New York
Boller Th., Trümper J., Molendi S., Fink H., Schaeidt S., Caulet A., Dennefeld M., 1993, A& A, 279, 53
Boller Th., Brandt W.N., Fink H., 1996, A&A, 305, 53 (BBF)
Boroson T.A., 1989, ApJ, 343, L9
Boroson T.A., Green R.F., 1992, ApJS, 80, 109
Boyle B.J., McMahon R.G., Wilkes B.J., Elvis M., 1995, MNRAS 272, 462
Brandt W.N., Fabian A.C., Nandra K., Reynolds C.S., Brinkmann W., 1994, MNRAS, 271, 958
Ciliegi P., Maccacaro T., 1996, MNRAS 282, 477
Dotani T. et al, 1996, ASCA News, 4,
Fabian A.C., Nandra K., Brandt W.N., Hayashida K., Makino F., Yamauchi M., 1995, in Proc of New Horizon of X-Ray Astronomy, eds, F. Makino and T. Ohashi, Universal Academy Press (Tokyo), p573
Ferland G.J., 1996, Hazy, a Brief Introduction to Cloudy. University of Kentucky Deptartment of Physics and Astronomy Internal Report
Fruscione A., 1996, ApJ, 459, 509
Gaskell C.M., 1985, ApJ, 291, 112
Goodrich R.W., 1989, ApJ, 342, 224
Gotthelf E., 1996, ASCA News, 4, 31
Green P.J., Mathur S., 1996, ApJ, 462, 637
Halpern J.P., 1984, ApJ, 281, 90
Halpern J.P., Oke J.B., 1987, ApJ, 312, 91
Heckman T.M., 1980, A&A, 87, 152
Iwasawa K., Fabian A.C., Brandt W.N., Crawford C.S., Almaini O., 1997a, MNRAS, submitted
Iwasawa K., Fabian A.C., Ueno S., Awaki H., Matsushita K., Makishima K., 1997b, MNRAS, 285, 683
Kachikian E., Weedman D., 1974, ApJ, 192, 581
Kallman T.R., McCray R., 1982, ApJ, 50, 263
Kollgaard R.I., Brinkmann W., Chester M.M., Feigelson E.D., Hertz P., Reich P., Wielebinski R., 1994, ApJS, 93, 145
Koski A.T., 1978, ApJ, 223, 56
Kriss G.A., Canizares C.R., 1982, ApJ, 261, 51
Laor A., Fiore F., Elvis M., Wilkes B.J., McDowell J.C., 1997, ApJ, 477, 93
Lawrence A., Elvis M.S., Wilkes B.J., McHardy I., Brandt W.N., 1997, MNRAS, 285, 879
Lipari S., 1994, ApJ, 436, 102
Makishima K. et al, 1994, PASJ, 46, L77
Mathur S., Elvis M., Singh K.P., 1995, ApJ, 455, L9
Morse J.A., Wilson A.S., Elvis M., Weaver K.A., 1994, ApJ, 439, 121
Nandra K., Mushotzky R.F., George I.M., Turner T.J., Yaqoob T., 1996, ApJ, in press
Osterbrock D.E., Pogge R.W., 1985, ApJ, 297, 166
Otani C., et al., 1996, PASJ, 48, 211
Reynolds C.S., 1997, MNRAS, 286, 513
Rigopoulou D., Lawrence A., Rowan-Robinson M., 1996, MNRAS, 278, 1049
Shuder J.M., Osterbrock D.E., 1981, ApJ, 250, 55
Stark A.A., Gammie C.F., Wilson R.W., Bally J., Linke R., Heiles C., Hurwitz M., 1992, ApJS, 79, 77
Tanaka Y., Inoue H., Holt S.S., 1994, PASJ, 46, L37
Veilleux S., Osterbrock D.E., 1987, ApJS, 63, 295
Weaver K.A. et al, 1994, 423, 621
Wilkes B.J., Elvis M., McHardy I., 1987, ApJ, 321, L23
Wilson A.S., Elis M., Bland-Hawthorn J., 1992, ApJ, 391, L75
Yaqoob T. et al, 1994, PASJ, 46, L49
Yaqoob T., Serlemitsos P.J., Ptak A., Mushotzky R.F., Kunieda H., Terashima Y., 1995, ApJ, 455, 508